

February 20, 1902.

Sir WILLIAM HUGGINS, K.C.B., D.C.L., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read :—

- I. "On Pure Cultures of a Uredine, *Puccinia dispersa* (Eriks.)." By Professor MARSHALL WARD, F.R.S.
- II. "On the Physics and Physiology of Protoplasmic Streaming in Plants." By Dr. A. J. EWART. Communicated by Professor GOTCH, F.R.S.
- III. "On a Pair of Ciliated Grooves in the Brain of the Ammocoete, apparently serving to promote the Circulation of the Fluid in the Brain-cavity." By Professor A. DENDY. Communicated by Professor HOWES, F.R.S.
- IV. "On the Interpretation of Photographic Records of the Response of Nerve obtained with the Capillary Electrometer." By G. J. BURCH, F.R.S.
- V. "Note on the Anomalous Dispersion of Sodium Vapour." By Professor W. H. JULIUS. Communicated by Professor C. V. BOYS, F.R.S.
- VI. "Note on Mr. Bateson's Paper, 'Heredity, Differentiation, and other Conceptions of Biology: a Consideration of Professor Karl Pearson's Paper "On the Principle of Homotyposis."'" By Professor KARL PEARSON, F.R.S.

"On Pure Cultures of a Uredine, *Puccinia dispersa* (Eriks.)."
By H. MARSHALL WARD, F.R.S. Received February 5,—
Read February 20, 1902.

During the course of a long series of experiments, designed to seek further information regarding the relations between the host and the parasite, in the case of certain species of *Bromus* and the Rust-fungus, *Puccinia dispersa* (Eriks.), it fell out that a simple method of obtaining pure cultures of both host and parasite was attainable.

Tube-cultures.

In order to obtain more decisive answers to such questions as—Are any of the results obtained on plants in the open, or merely covered with bell-jars and so forth, due to spores accidentally introduced, or to mycelium, &c., already in the plant?—a number of infections were made on seedlings germinated and grown anti-septically in tubes as follows:—

As a preliminary trial, to test whether grass seedlings would live long enough in tubes and show the results of infection, I placed seedlings, all similar, and bearing three to four leaves, in test-tubes, the roots, carefully washed free of soil, resting on wet cotton wool, and the orifice of the tube plugged. The results of two series apparently showed that spores from *B. mollis* infect *B. mollis* and *B. sterilis*,* *B. secalinus* and *B. arvensis*, but not *B. inermis*, while spores grown on *B. sterilis* only infected *B. secalinus* and *B. arvensis* (see Table I).

It is a striking fact that under the conditions afforded by these closed tubes, with their stagnant moist atmosphere, spores from *B. sterilis* apparently succeeded in infecting *B. secalinus* and *B. arvensis*. The pustules were small, and it is significant that it took 14 days' incubation to establish the mycelium, against 9 days in the case of spores from *B. mollis*.

There are, however, other slight departures from the usual course of events—e.g., spores from *B. mollis* failed on *B. arvensis* and succeeded on *B. sterilis*—which may point to the probability that these uprooted seedlings in tubes are not in their normal conditions. The facts seem worth recording in this connection.

I varied these tube-cultures by placing them, after infection, under cuvettes filled with copper sulphate (blue light) or bichromate of potassium (orange light). The results were somewhat contradictory as regards the blue, but it did appear that the spores coming from *B. mollis* can infect *B. sterilis* as well as *B. secalinus*, as the following Table II shows.

It is important here to bear in mind the origin of the seedlings themselves, however, as a serious source of error was discovered in these uprooted seedlings, previously exposed to possible infection in the open.

The same criticisms, in fact, apply to these transplanted garden seedlings in tubes as I have given elsewhere regarding such experiments in pots, viz., it was always possible that the seedling was already infected, or had wind-blown spores on it when removed from the beds. At the same time the long incubation period, 14 days in some cases, fails to support this.

* An exceptional circumstance, as numerous experiments have shown, and itself sufficient to raise the criticism which follows.

Table I.—Three-leaved Seedlings in closed Test-tubes, on wet Cotton-wool, kept at N. Window and infected forthwith with Spores from *B. mollis* and *B. sterilis*.

Exp. No.	Date.	Host.	Origin of spores.	Result.*	Incubation period.	Period of experiment.	Remarks.
697	May 25	<i>B. inermis</i> . . .	<i>B. sterilis</i>	—	..	21 days	Leaf yellow and faded by June 3.
"	"	<i>B. sterilis</i>	"	—	..	"	"
"	"	<i>B. mollis</i>	"	—	..	"	"
"	"	<i>B. scabrinus</i> . .	"	+	14 days	"	Pustules very small.
"	"	<i>B. arvensis</i> . . .	"	+	"	"	"
705	May 30	<i>B. mollis</i>	<i>B. mollis</i>	+	9 days	"	Two leaves still green at end of experiment.
"	"	<i>B. arvensis</i> . . .	"	—	..	"	"
"	"	"	"	+	9 days	"	Two green leaves left at end.
"	"	<i>B. inermis</i>	"	—	..	"	"
"	"	<i>B. sterilis</i>	"	+	9 days	"	"
"	"	<i>B. scabrinus</i> . . .	"	+	"	"	"

* In all cases the sign + signifies that spore-bearing pustules were developed; the sign — that no signs of infection were visible.

Table II.—Test-tubes with Seedlings (as in Experiment 697) infected on Third Leaf and then put under Cuvettes of CuSO_4 and K bichromate respectively, and kept in the garden fully exposed to sun during mid-day.

Exp. No.	Date.	Host species.	Origin of spores.	Result.		Incubation.	Colour of light.	Remarks.
698	May 25	<i>B. sterilis</i> ..	<i>B. mollis</i>	+		14 days	Orange-red	
"	"	"	"	+	—	"	"	
"	"	"	"		—		Blue	No trace of pustules, though two leaves still green.
"	"	"	"				"	"
709	June 11	"	"	+		10 days	Orange-red	
"	"	"	"	+		11 "	"	
"	"	"	"	+		11 "	"	
"	"	"	"		—	11 "	Blue	
"	"	"	"		—	11 "	"	On the 22nd, however, I note that the cuvette leaked above and has let in white light.
"	"	<i>B. secalinus</i>	"	+		11 "	"	
"	"	"	"	+		11 "	"	
"	"	"	"			11 "	"	
"	"	"	"		—	10 "	Orange	
"	"	"	"	+		10 "	"	

To meet this objection I devised operations as follows :—

Clean picked seeds were placed singly, by means of forceps, on filter paper at the bottom of Petri-dishes properly sterilised by heat. When these had germinated, and observation showed that the whole series was free of moulds or other signs of contamination, the seedlings were removed by means of sterile forceps, and transplanted singly into sterilised tubes of various kinds as described below, and the further growth allowed to proceed in the light under conditions varied as will be seen.

I had already shown that seedlings will continue to grow in such tubes, but, as we have seen, in the cases previously described I had no guarantee that the seedlings introduced into the culture-tubes did not already carry on their leaves wind-borne or otherwise transmitted spores.

In the case of these seedlings germinated from clean “seed” in sterile dishes and tubes, it is obvious that the only chance of infection depends on spores attached to the “seed” or on mycelium in the seed.

Experiments with seed gathered even from badly rusted plants and germinated as above, have never given rusted seedlings, although other experiments have shown me that the germ-tubes of attached spores can infect seedlings when the plumule is only 3—5 mm. high. Nor have I ever been able to discover any trace of mycelium in the seeds.

But if the “seed” of the *Bromus* is sterilised before germination—as can be done by steeping in various antiseptics, or by heating to 60—70° C.—it is found that pure cultures of the Brome may be obtained in the tubes, and it is then only necessary to infect such a clean seedling with the spores of the parasite to obtain a pure culture of the latter.

Preliminary experiments soon showed that the Brome seedlings thus raised from seeds treated antiseptically, and protected from the first by glass, may be grown for weeks and even for a couple of months in such tubes under proper precautions, and I set myself the task of ascertaining how such cultures would behave in infection experiments.

In the following experiment—No. 711—eight upright tubes of the kind known to chemists as “drying towers,” were prepared as in the diagram (fig. 1), so that by means of an aspirator attached to the tubing at G, a continuous current of damp air could be slowly drawn through the whole series, aërating the roots of the seedlings F, which burrowed into the cotton-wool B, day and night. The tubes were charged each with one seedling, grown from seeds heated to 65° C., and 48 hours after germination had begun, and the latter allowed to grow in the light on a table outside the laboratory. The tubes were charged on June 14, and on June 19, when the first green leaf was well developed, the latter was infected at a definite spot with spores—proved

to be capable of vigorously germinating by cultures in hanging drops—and the whole series linked up and aerated. The growth of these seedlings in the moist air-current was very satisfactory, the plants

FIG. 1.

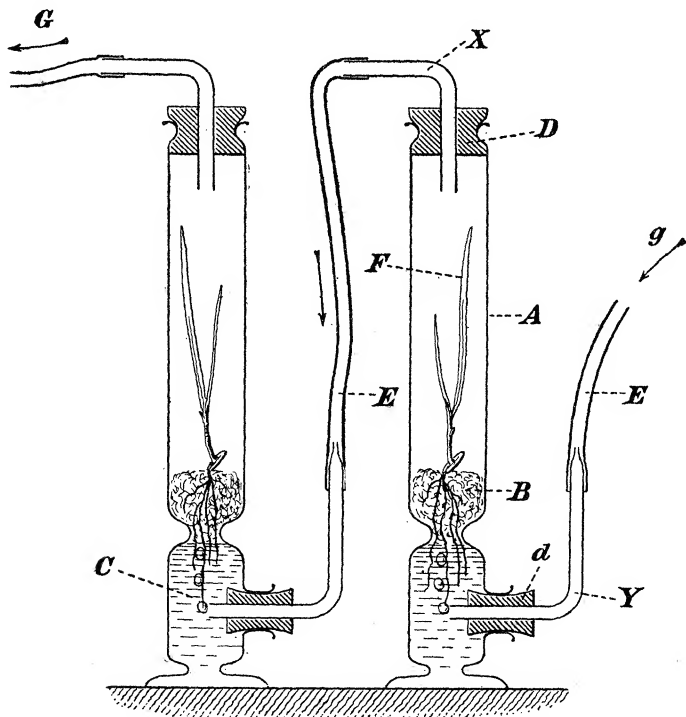


Diagram showing arrangement of tubes for pure cultures of grass seedlings—see text—here shown connected up for aëration. Reduced.

A = glass jar. B = cotton-wool saturated with liquid. C = liquid reservoir containing nutritive culture solution, through which air bubbles pass. D and d = caoutchouc stoppers pierced by glass tubing. EE = caoutchouc tubing. F = seedling with its roots in B and its leaves in air. G and g = arrows showing direction of air current. x and y = glass tubes.

having a deep rich green colour, though the leaves were short, and the results, as shown in the following Table III, were very instructive.

In this series the liquid employed was the normal Knop's mineral solution (+), so well known as used in water-cultures. The tubes were charged with this before sterilisation, enough being put in to wet the cotton-wool plug (B), and fill the reservoir (C), the side-tube y being fused at its pointed end during sterilising.

Table III.—Experiments in Aërated and in Closed Tubes. Selected and Sterilised Seeds and Clean Seedlings.
Infected when one week old. Roots in Knop's Solution.

Expt. No.	Date.	Host.	Origin of spores.	Treatment.	Results.	Period of incu- bation.	Period of expe- riment.	Remarks.
711	June 19	<i>B. sterilis</i>	<i>B. mollis</i>	Aërated continuously	—	21 days		
"	"	"	"	"	—	"		
"	"	<i>B. mollis</i>	"	"	+	12 days		
"	"	"	"	"	+	16 "		
712	"	<i>B. sterilis</i>	"	"	—	"		
"	"	"	"	"	—	"		
"	"	"	"	"	—	"		
"	"	<i>B. mollis</i>	"	"	?	"		Flecks developed, but no spores formed.
"	"	"	"	"	?	"		"
713	"	"	"	Closed tubes.	+	8 "		
"	"	"	"	"	+	12 "		
"	"	<i>B. sterilis</i>	"	"	—	"		
"	"	"	"	"	—	"		
"	"	<i>B. velutinus</i> . .	"	"	+	10 "		Very fine growth of sporiferous pustules.
"	"	<i>B. maximus</i> . .	"	"	—	"		
"	"	<i>B. madriensis</i> .	"	"	—	"		
"	"	<i>B. commutatus</i>	"	"	—	"		
"	"	<i>B. arvensis</i> . . .	"	"	+	10 "		
"	"	"	"	"	—	"		
"	"	<i>B. secalinus</i> . . .	"	"	+	8 "		Very fine pustules.
"	"	<i>B. interruptus</i>	"	"	+	10 "		
"	"	"	"	"	+	11 "		
"	"	<i>B. racemosus</i> . .	"	"	+	"		

Since each tube is linked to its neighbour with clean flexible tubing, and the air bubbles through the liquid in the reservoir (C), and has to pass the cotton-wool plug (B) before reaching the leaves (F) in the air above, there can be no question of infection from outside, and the results also show that *infection only occurs exactly where I place the spores on the leaf in each case.*

The spores employed were carefully tested as regards their germinating power, and, as the table shows, the results in the closed tubes fully bear out previous experience. In the aspirated tubes, however, the second pair of seedlings of *B. mollis* (No. 712) gave negative results, inasmuch as only flecks, and not pustules bearing spores, were developed. In the closed tubes, however—see below—the positive results, especially on *B. velutinus* and *B. secalinus*, were excellent, and subsequent examination showed that the spores germinated well, and were capable of infecting other seedlings.

In order to test further the behaviour in mineral solutions, I prepared, as Table III shows, several series in closed tubes, Nos. 713, which served as a parallel series to Nos. 711 and 712, but without aëration.

In No. 713 the sterile seedlings were raised antiseptically as before, but the roots merely penetrated cotton-wool saturated with Knop's solution, and held by the constriction over the bulb filled with the same, no air being drawn through.

The growth was excellent, and the results very conclusive, as Table III shows.

The seedlings were allowed two days at 22—20° C. in the laboratory and then put out side by side with 711 and 712 in full sun during the middle of the day, and after two days' further growth were infected.

By the 10th day the thin leaf was well developed, and the first pustule was seen on *B. mollis* and *B. secalinus* on the eighth day after infection. The Table III shows the course of events in detail.

The growth of pustules was excellent on *B. velutinus* and *B. secalinus* especially.

This experiment is interesting, not only as showing that plants can be grown and infected successfully in these closed water-cultures, but especially as showing the contrast between the aërated and non-aërated tubes, for, since the infected seedlings were selected in each case from the same Petri-dish cultures, we must assume that the difference in rate of development was due to the difference of ventilation, and perhaps conclude that this interferes with the success of the parasite, as measured by the somewhat longer incubation period. It is remarkable how dwarfed the continuously aërated plants are, compared with those in closed tubes, owing to the elongation of the leaves of the latter.

It is clear, therefore, that pure cultures of Uredo-spores can be obtained by this method, and it is equally clear that we can also obtain

pure cultures of the host-plants, and since we can do this, there is no reason why the infection of *Uredineæ* should not be conducted as rigorously and exactly as that of bacteria. As matter of fact, I have succeeded in proving that it can,* though of course the length of time occupied in a large series of cultures and infections will prove troublesome, and it remains to be seen whether we can get such plants to flower.

The following Table IV gives the results of an additional series where *B. secalinus* was the host, and spores from the same used as as infecting material. In this case the tubes used were closed from the first (see fig. 2). These results appear to me to dispose effectually of the question as to whether or not pure cultures of *Uredineæ* can be obtained.

A number of isolated tube-cultures were made with spores from *B. sterilis*, *B. mollis* and *B. secalinus*, and arranged similarly, and confirmatory results obtained. Moreover, I was able in several cases to transfer successfully spores from these pure tube-cultures to other tubes of pure cultures of seedlings, and to prove that the spores raised under strictly antiseptic conditions are capable of germination and infection.

At the same time, it was noteworthy that in several cases the antiseptically raised spores were not always successful in infecting the seedlings, and it remains for further investigation to determine whether this was due to the conditions of culture of the fungus or the host or both.

Experiments with Mineral Supplies.

The question arose during some of the tube-experiments, Do infection and incubation occur normally if the host-plant is suffering from a lack of any particular ingredient in the soil—*e.g.*, one of the essential minerals? To answer this, I prepared tube-cultures as before—as in experiments Nos. 711 and 713, &c.—substituting for the normal nutritive solution, in some of the tubes, the same solution minus calcium, or minus potassium, or magnesium or phosphoric acid, respectively, with the results shown in the following Table V. The only positive result was with spores from *B. mollis*, which infected *B. mollis* in spite of the lack of Mg salts. In other cases flecks only were developed.

This experiment cannot be regarded as very decisive, but it at least shows that infection *can* occur when Mg is lacking, though the incubation period (13 days) was somewhat long. As the pot-cultures show, no positive results were to be expected with *B. maximus* infected from *B. mollis*.

* *I.e.*, of course so far as fungi are concerned: the antiseptic treatment adopted does not always exclude harmless bacteria.

TABLE IV.—Closed Tubes of Antiseptic Seedlings (Seeds Sterilised at 65° C.) in Nutritive Solutions. Tubes merely Plugged, and Seedlings on wet Plug with Solution below. Kept in moderate Sunshine.

No.	Date.	Host.	Origin of spores.	Nutritive solution.	Aerated or not.	Results.			Remarks.
						July 29.	July 30.	July 31.	
772 a.....	July 19.	<i>B. secalinus.</i>	<i>B. secalinus.</i>	Pfeffer normal	not	+	+	+	
" b.....	"	"	"	"	"	0	+	+	
" c.....	"	"	"	"	"	+	+	+	
" c'.....	"	"	"	"	"	0	0	+	
" d.....	"	"	"	"	"	+	+	+	
" d'.....	"	"	"	"	"	+	+	+	
" e.....	"	"	"	Pfeffer without Fe	"	+	+	+	
" e'.....	"	"	"	"	"	+	+	+	
" f.....	"	"	"	Detmer, without K	"	+	+	+	
" f'.....	"	"	"	"	"	0	0	0	
" g.....	"	"	"	Detmer, without P	"	+	+	+	
" g'.....	"	"	"	"	"	0	+	+	

The following experiment (Table VI) seems at first sight very suggestive in its definite results, but much more work will be needed before we can generalise widely. Five tubes with bulbs below were charged with a seedling each of *B. arvensis* and five with *B. velutinus*, one of each five tubes having normal Detmer's solution, one the same minus K, Ca, &c., respectively. The seedlings were 10 days old, grown antiseptically on moist filter paper, and therefore exhausting the reserves, and would probably come at once under the full influence of the mineral solutions.

Each seedling was infected forthwith with spores from *B. mollis*, tested, and found to be not very vigorous in germination. Since all were infected alike, however, on the first leaf and from the same batch of spores, I think we must regard the results as fairly comparable.

As the table shows, every plant of *B. velutinus* had spore-bearing pustules in 10—11 days, whereas the *B. arvensis* gave no signs, if we except one doubtful pustule on the 11th day in the tube devoid of potassium.

It seems necessary to conclude from this series that *B. arvensis* is far less easily infected than *B. velutinus* under any conditions of mineral supply afforded. The experiment also shows that in the case of a susceptible plant such as *B. velutinus*, no appreciable effect is produced by the mineral supply in the short time (10—11 days) occupied in incubation. Something may turn out to be due to the differences in size of the seeds, however.

Meanwhile I had made some experiments on seedlings started in pots of coir-fibre, under conditions more

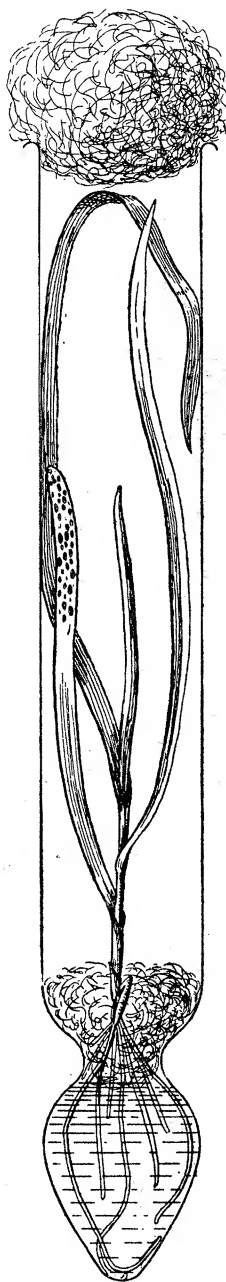


FIG. 2.—Pure culture of *Puccinia dispersa* on *Bromus velutinus*. The "seed" of the grass, antiseptically sterilised as regards fungus spores by heating to 65° C., was germinated in the sterile tube, and infected on the first leaf with spores developed on *Bromus mollis*. The infection was successful, and pustules of spores have appeared *only on the area inoculated*. About natural size.

Table V.—Large Tube-cultures of Seedlings, Germinated on Damp Filter-paper for six days, and then placed with their Roots in Mineral Solutions, and infected two days later.

Expt. No.	Species.	Origin of spores.	Nutritive solution.	Result.	Period of incubation.	Duration of experiment.	Remarks.
714	<i>B. mollis</i>	<i>B. mollis</i> ...	Water only.....	—		21 days	A yellow fleck.
"	"	"	Normal Detmer*..	—		"	* Plant lost.
"	"	"	Minus Ca.....	—		"	A fleck.
"	"	"	" K.....	—	13 days	"	Flecks.
"	"	"	" Mg.....	—	"	"	} No infection anywhere visible.
"	"	"	" P ₂ O ₅	—	"	"	
"	<i>B. marimus</i> ..	"	Water only.....	—	"	"	
"	"	"	Normal Detmer..	—	"	"	
"	"	"	Minus Ca.....	—	"	"	
"	"	"	" K.....	—	"	"	
"	"	"	" Mg.....	—	"	"	
"	"	"	" P ₂ O ₅	—	"	"	

Table VI.—Exactly as 715, but Seedlings ten days old and already exhausting their reserves.

Expt. No.	Species.	Origin of spores.	Nutritive solution.	Result.	Period of incubation.	Duration of experiment.	Remarks.
721 & 722	<i>B. arvensis</i> ...	<i>B. mollis</i> ...	Normal Detmer...	—	11 days?	21 days	{ Fleck only, or at most bearing a few spores.
"	"	"	Minus Ca.....	—	"	"	
"	"	"	" K.....	—	"	"	
"	"	"	" Mg.....	—	"	"	
"	"	"	" P ₂ O ₅	—	"	"	
"	<i>B. velutinus</i> ..	"	Normal Detmer...	—	"	"	
"	"	"	Minus Ca.....	—	11	"	}
"	"	"	" K.....	—	10	"	
"	"	"	" Mg.....	—	11	"	
"	"	"	" P ₂ O ₅	—	11	"	
"	"	"	"	—	10	"	

nearly approaching the normal than, perhaps, the tubes afford, to see if the influence of mineral supplies, or lack of such, at the roots affects the questions before us.

Seeds of four species of *Brome* were sown in pots of coco-fibre (coir) thoroughly steamed in a steriliser. The seedlings—all except *B. asper*—came up satisfactorily, but did not form strong plants eventually. As the following Table VII shows, infection failed in all cases, in spite of the fact that the seedlings were given a double dose of spores. It is difficult to explain the negative results with *B. mollis*. The temptation is to conclude that the host-plant, being starved of mineral supplies, gave the infecting germ-tube no chance to establish itself, but I think much more work must be done before this is established.

The following experiments, however, yielded results which seem to show that the nature or amount of the mineral supply may after all be not without effect.

Small pots were packed with washed coco-nut fibre and sterilised by steam, and “seeds” of *B. mollis* sown in twelve of them. Germination was started at 27° C. in the artificial greenhouse and the pots then placed in a well-lighted, ordinary greenhouse and watered as follows:—Two with Detmer’s normal solution, and two each with the same minus K, Ca, Mg, and P_2O_5 respectively, while two were kept as controls watered with distilled water.

On the 5th day the spears were up and the first leaf unfolding, and one pot of each pair mentioned infected with spores from *B. mollis*. The parallel set were similarly infected, with spores from *B. mollis*, two days later, a different crop of spores being used.

After four days’ incubation under wet beakers—in the case of the first six pots—and two days—in the case of the second six—all were put out side by side in a sunny place under a large bell-jar. Two days later the bell-jar was removed. The pots were placed well apart, each in its own saucer, and equal carefully measured doses of the minerals given at intervals.

The seedlings grew admirably at first, but began to show the effects of the mineral deficiency in a few days. Meanwhile the incubation period was being completed. The results appear in Table VIII. There were, however, very marked points of difference between the appearances in this series 716 and those seen in perfectly normal plants—*e.g.*, series 735—736 and 738.

In the first place, none of the pustules or disease-flecks were very large or well developed. They were, curiously enough, best on the seedlings provided with water only. Next best on those with normal mineral solution, and on those with the same devoid of Ca, and (another curious fact) in one case on the plants deprived of Mg. On those deprived of P_2O_5 or of K the development was distinctly worse.

Table VII.—Seedlings sown in Coco-fibre on May 24. Infected May 29, and re-infected May 30, in each case in Tip-drops. Water only used to keep the Coir damp.

Experi- ment No.	Date of infection.	Host.	Origin of spores.	No. of plants.	No. inocu- lated.	Results.			Remarks.
						July 8.	July 11.	July 15.	
702 (1)	May 29	<i>B. inermis</i> ..	<i>B. mollis</i> ...	25	10	0	0	0	
" (2)	"	"	" ...	"	"	0	0	0	
" (3)	"	<i>B. mollis</i> ...	" ...	"	"	0	0	0	
" (4)	"	" ...	" ...	"	"	0	0	0	
" (5)	"	<i>B. sterilis</i> ..	" ...	"	"	0	0	0	
" (6)	"	" ..	" ...	"	"	0	0	0	
" (7)	"	<i>B. asper</i> ...	" ...	"	"	..	..	..	} Did not come up.
" (8)	"	" ..	" ...	"	"	..	..	..	

Table VIII.—Seedlings in Sterilised Pots of Coco-fibre, saturated with Mineral Culture Solutions, and infected after 5—7 days, in Greenhouse.

Expt. No.	Date of sowing.	Host.	Origin of spores.	Nutritive solution.	Date of infection.	Result.	Period of incubation.	Duration of experiment.	Remarks.
716 <i>a</i>	June 17	<i>B. mollis</i>	<i>B. mollis</i>	Water only.....	June 22	+	10 days	24 days	Excellent plants and pustules.
" <i>b</i>	"	"	"	Normal Detmer	"	+	11 "	"	Rather pale, but good pustules.
" <i>c</i>	"	"	"	Minus Ca.....	"	+	12 "	"	Fair plants; pustules small.
" <i>d</i>	"	"	"	" K.....	"	+	12 "	"	Some leaves shrivelled; pustules few and small.
" <i>e</i>	"	"	"	" Mg.....	"	+	13 "	"	Good plants and pustules.
" <i>f</i>	"	"	"	" P ₂ O ₅	"	+	13 "	"	Plants elongated and pale; only one minute and poor pustule.
" <i>g</i>	"	"	"	Water only.....	June 24	+	12 "	22 days	Fair plants; one pustule; several flecks.
" <i>h</i>	"	"	"	Normal Detmer	"	+	12 "	"	Fairly normal plants and pustules.
" <i>i</i>	"	"	"	Minus Ca.....	"	+	12 "	"	Pustules small; some leaves shrivelled.
" <i>k</i>	"	"	"	" K.....	"	—	"	"	Much shrivelled; no pustules.
" <i>l</i>	"	"	"	" Mg.....	"	—	"	"	Pale and with shrivelled tracts.
" <i>m</i>	"	"	"	" P ₂ O ₅	"	—	"	"	Pale, drawn, and shrivelling.

These results also accord with the appearance of the plants themselves. The want of P_2O_5 results in a long limp growth, and very pale colour, and the attacked spots show corrosion and collapse instead of normal flecks.

Similarly, in plants deprived of K we have pale collapsing patches in place of normal flecks, though the plant is not drawn and etiolated as in the previous case. Where Mg was wanting the drawing and paleness of the leaves were not so marked, and the fungus flecks in the positive case were more like the normal.

That a want of supplied Ca should have very little effect on either host or parasite, was no doubt due to there being small quantities available in the soil and pots. The flecks and pustules were apparently normal, though small.

It is not easy to see why the pots with water only yielded plants with flecks as good as, or even better than those with normal solution, unless the concentration of the salts affects the fungus. However it is probably not to be inferred that in any of these cultures the grass was totally deprived of the given salt—it would get traces from the pots and coir in any case—but the effects of deprivation of salts ought certainly to be felt, and I think were so to some extent in lengthening the incubation period.

So far as the results go they suggest that differences in the supply of minerals affects the development of mycelium and of spores owing to effect on the host—in cultivating the host we also cultivate the parasite.

But I would insist that these trials with special mineral-supplies are merely preliminary. The task in hand was far too extensive for the problems to be solved in one season, and I contemplate carrying the whole matter—or persuading some one to do so—much farther in the future. Meanwhile, the results give suggestions for further work, and much remains to be done along the lines I have here laid down, as well as in directions yet to be opened out.

“On the Physics and Physiology of the Protoplasmic Streaming in Plants.” By ALFRED J. EWART, B.Sc. (Oxon.), D.Sc. (Lond.), Ph.D., F.L.S., Lecturer on Botany in the Birmingham Technical Institute. Communicated by FRANCIS GOTCH, D.Sc., F.R.S. Received January 17,—Read February 20, 1902.

(Abstract.)

The results of an extended series of observations upon this phenomenon have led the author to conclusions which may be summarised as follows:—

FIG. 1.

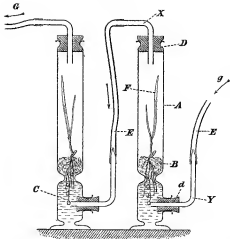


Diagram showing arrangement of tubes for pure cultures of grass seedlings—see text—here shown connected up for aeration. Reduced.

A = glass jar. B = cotton-wool saturated with liquid. C = liquid reservoir containing nutritive culture solution, through which air bubbles pass. D and d = caoutchouc stoppers pierced by glass tubing. E = caoutchouc tubing. F = seedling with its roots in B and its leaves in air. G and g = arrows showing direction of air current. X and Y = glass tubes.

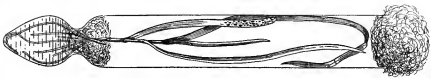


FIG. 2.—Pure culture of *Puccinia diaporae* on *Bromus reliquus*. The "seed" of the grass, antiseptically sterilized as regards fungus spores by heating to 65°C ., was germinated in the sterile tube, and infected on the first leaf with spores developed on *Bromus mollis*. The infection was successful, and pustules of spores have appeared only on the area inoculated. About natural size.